Appendix B

Comparison between ISLAB2000 Results and Westergaard's Solution

Comparison between ISLAB2000 results and Westergaard's solution

Each problem was divided into two parts: the textbook solution (Huang, 1993), and the ISLAB2000 solution (FE solution). The textbook solution consists of the problem statement, an illustration of the problem, and solution based on Westergaard's equations, while the finite element (FE) solution consists of the summary of inputs, illustration of the mesh and loading used in problem, followed by a short explanation if necessary, and numerical graphical outputs.

Problem 1 (Example 4.1 page 172 in the textbook)

Textbook solution

Given:	Concrete elastic modulus	=	$4*10^6$	psi
	Concrete Poisson ratio	=	0.15	
	Slab length	=	25	ft
	Slab width	=	12	ft
	Slab thickness	=	8	in.
	Temperature differential	=	20	^oF
	k-value	=	200	psi/in.
	α_t	=	$5*10^{-6}$	in./in./ ^oF

Find: (a) The maximum curling stress in the interior of the slab
(b) The maximum curling stress at the edge of the slab

Problem illustration:

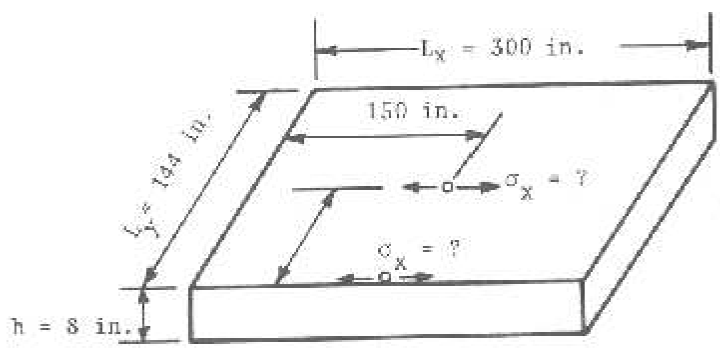

Figure B-1: Problem illustration (Figure 4.5 in the textbook)

Solutions (based on Westergaard's equations):

(a) The maximum curling stress in the interior of the slab = 238 psi (1641 kPa)
(b) The maximum curling stress at the edge of the slab = 214 psi (1476 kPa)

FE solution

Summary of inputs: All pavement features and temperature gradients used in this part are the same as indicated in the textbook solution. For the finite element model, fine mesh size (6”), medium mesh size (12”), coarse mesh size (24”), and manual mesh size (3”) with mesh aspect ratio of one were chosen. It should be noted that these are the mesh configurations used for the rest of the analysis using ISLAB2000 in this report unless otherwise indicated. An illustration of the fine mesh size, which is a default in the software, is shown below.

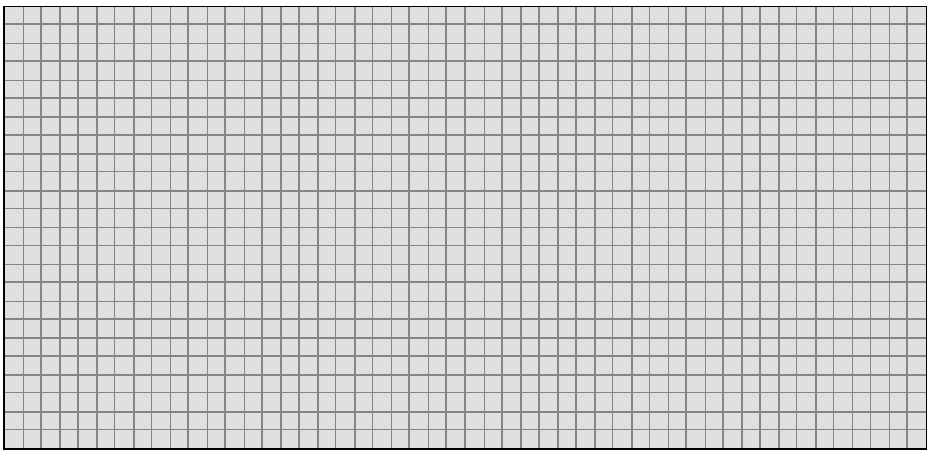

Figure B-2: Mesh used for finite element model in ISLAB2000

Numerical outputs:

<u>For fine mesh</u>:
- The maximum stress in the interior of the slab = 230.3 psi (1588 kPa)
- The maximum stress at the edge of the slab = 220.3 psi (1519 kPa)

<u>For medium mesh</u>:
- The maximum stress in the interior of the slab = 230.1 psi (1587 kPa)
- The maximum stress at the edge of the slab = 220.1 psi (1518 kPa)

<u>For coarse mesh</u>:
- The maximum stress in the interior of the slab = 231.6 psi (1597 kPa)
- The maximum stress at the edge of the slab = 219.0 psi (1510 kPa)

<u>For manual mesh</u>:
- The maximum stress in the interior of the slab = 230.5 psi (1589 kPa)
- The maximum stress at the edge of the slab = 219.8 psi (1516 kPa)

Result comparison:

Table B-1: Maximum curling stress in the interior of the slab comparison

Approach	Maximum Curling Stress		Difference (%)
	(psi)	(kPa)	
Westergaard's	238.0	1641	0.00
ISLAB2000 (24" mesh size)	231.6	1597	2.69
ISLAB2000 (12" mesh size)	230.1	1587	3.31
ISLAB2000 (6" mesh size)	230.3	1588	3.25
ISLAB2000 (3" mesh size)	230.5	1590	3.14

Table B-2: Maximum curling stress at the edge of the slab comparison

Approach	Maximum Curling Stress		Difference (%)
	(psi)	(kPa)	
Westergaard's	214.0	1476	0.00
ISLAB2000 (24" mesh size)	219.0	1510	2.35
ISLAB2000 (12" mesh size)	220.1	1518	2.87
ISLAB2000 (6" mesh size)	220.3	1519	2.95
ISLAB2000 (3" mesh size)	219.8	1516	2.72

Problem 2 (Example 4.2 page 176 in the textbook)

Textbook solution

Given: Concrete elastic modulus = $4*10^6$ psi
Concrete Poisson ratio = 0.15
Slab thickness = 10 in.
k-value = 100 psi/in.
Tire contact radius = 6 in.
Wheel load = 10,000 lb

Find: (a) The maximum stress due to corner loading
(b) The maximum deflection due to corner loading

Problem illustration:

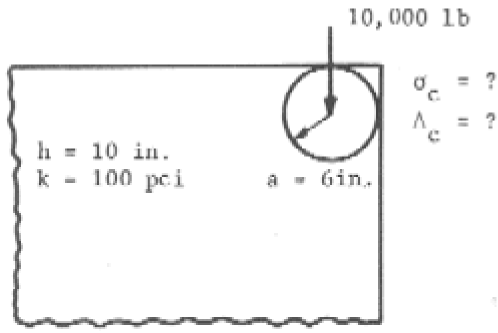

Figure B-3: Problem illustration (Figure 4.7 in the textbook)

Solutions (based on Westergaard's equations):

(a) The maximum stress due to corner loading = 186.6 psi (1287 kPa)
(b) The maximum deflection due to corner loading = 0.0502 in. (1275 microns)

FE solution

Summary of inputs: All pavement features used in this part are the same as indicated in the textbook solution. However, the circular tire contact area as illustrated in the problem is not an option in ISLAB2000. As a result, a square tire contact area with the same tire contact pressure and wheel load was used instead. The tire contact pressure will be used again in problems 3 and 4. The tire pressure is computed as follows.

Tire contact pressure, $q = \dfrac{P}{\pi \cdot a^2} = \dfrac{10{,}000}{\pi \cdot 6^2} = 88.42 \quad psi$ (A-1)

Figures A4 and A5 represent the mesh used in the analysis.

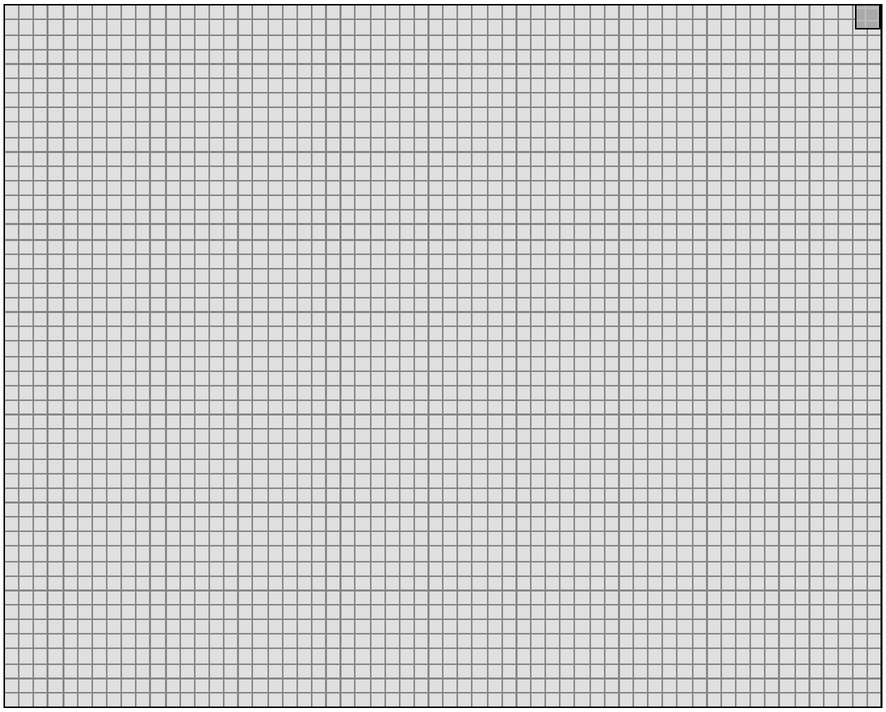

Figure B-4: Mesh used for finite element model in ISLAB2000

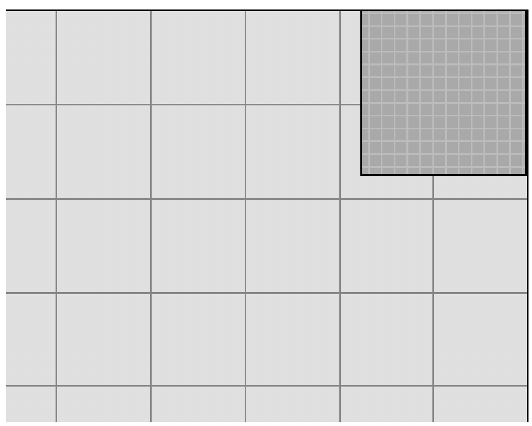

Figure B-5: Equivalent square contact area used in ISLAB2000

Numerical outputs:

For fine mesh:

The maximum stress due to corner loading	= 195.8	psi (1350 kPa)
The maximum deflection due to corner loading	= 0.0563	in. (1430 microns)

For medium mesh:

The maximum stress due to corner loading	= 197.9	psi (1365 kPa)
The maximum deflection due to corner loading	= 0.0563	in. (1430 microns)

For coarse mesh:

The maximum stress due to corner loading	= 198.4	psi (1368 kPa)
The maximum deflection due to corner loading	= 0.0562	in. (1427 microns)

For manual mesh:

The maximum stress due to corner loading = 195.8 psi (1350 kPa)

The maximum deflection due to corner loading = 0.0563 in. (1430 microns)

Result comparison:

Table B-3: Stress result comparison

Approach	Maximum Curling Stress		Difference (%)
	(psi)	(kPa)	
Westergaard's	186.6	1287	0.00
ISLAB2000 (24" mesh size)	198.4	1368	6.32
ISLAB2000 (12" mesh size)	197.9	1365	6.06
ISLAB2000 (6" mesh size)	195.8	1350	4.93
ISLAB2000 (3" mesh size)	195.8	1350	4.93

Table B-4: Deflection result comparison

Approach	Maximum Deflection		Difference (%)
	(in.)	(microns)	
Westergaard's	0.0502	1275	0.00
ISLAB2000 (24" mesh size)	0.0562	1427	11.95
ISLAB2000 (12" mesh size)	0.0563	1430	12.15
ISLAB2000 (6" mesh size)	0.0563	1430	12.15
ISLAB2000 (3" mesh size)	0.0563	1430	12.15

Table B-5: Stress result comparison

Approach	Maximum Curling Stress		Difference (%)
	(psi)	(kPa)	
Ioannides's	190.2	1311	0.00
ISLAB2000 (24" mesh size)	198.4	1368	4.31
ISLAB2000 (12" mesh size)	197.9	1365	4.05
ISLAB2000 (6" mesh size)	195.8	1350	2.94
ISLAB2000 (3" mesh size)	195.8	1350	2.94

Table B-6: Deflection result comparison

Approach	Maximum Deflection		Difference (%)
	(in.)	(microns)	
Ioannides's	0.0560	1422	0.00
ISLAB2000 (24" mesh size)	0.0562	1427	0.36
ISLAB2000 (12" mesh size)	0.0563	1430	0.54
ISLAB2000 (6" mesh size)	0.0563	1430	0.54
ISLAB2000 (3" mesh size)	0.0563	1430	0.54

Problem 3 (Example 4.3 page 177 in the textbook)

Textbook solution

Given:	Concrete elastic modulus	=	$4*10^6$	psi
	Concrete Poisson ratio	=	0.15	
	Slab thickness	=	10	in.
	k-value	=	100	psi/in.
	Tire contact radius	=	6	in.
	Wheel load	=	10,000	lb

Find: (a) The maximum stress due to interior loading
(b) The maximum deflection due to interior loading

Problem illustration:

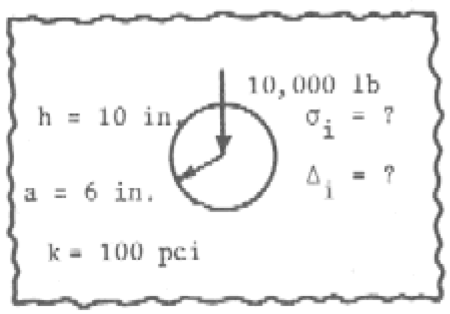

Figure B-6: Problem illustration (Figure 4.8 in the textbook)

Solutions (based on Westergaard's equations):

(a) The maximum stress due to interior loading = 143.7 psi (991 kPa)
(b) The maximum deflection due to interior loading = 0.00670 in. (170 microns)

FE solution

Figures A7 and A8 represent the mesh used in the analysis.

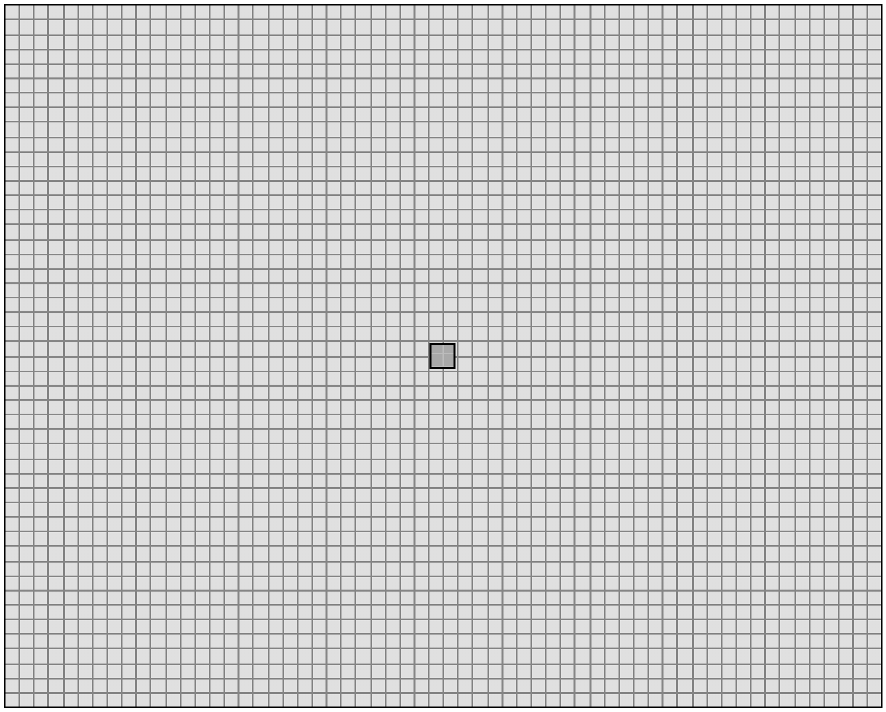

Figure B-7: Mesh used for finite element model in ISLAB2000

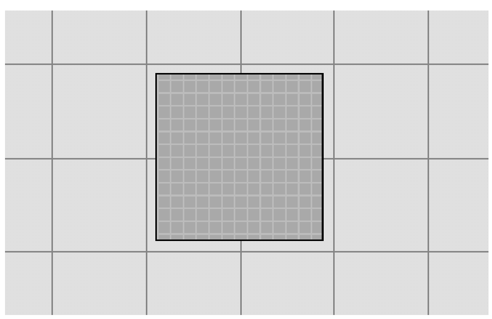

Figure B-8: Equivalent square contact area used in ISLAB2000

Numerical outputs:

For fine mesh:
The maximum stress due to interior loading = 151.9 psi (1047 kPa)
The maximum deflection due to interior loading = 0.00690 in. (175 microns)
For medium mesh:
The maximum stress due to interior loading = 159.0 psi (1096 kPa)
The maximum deflection due to interior loading = 0.00692 in. (176 microns)
For coarse mesh:

The maximum stress due to interior loading = 140.6 psi (969 kPa)
The maximum deflection due to interior loading = 0.00683 in. (173 microns)

<u>For manual mesh</u>:

The maximum stress due to interior loading = 144.2 psi (994 kPa)
The maximum deflection due to interior loading = 0.00689 in. (175 microns)

Result comparison:

Table B-7: Stress result comparison

Approach	Maximum Deflection		Difference (%)
	(in.)	(microns)	
Westergaard's	0.00670	170	0.00
ISLAB2000 (24" mesh size)	0.00683	173	1.94
ISLAB2000 (12" mesh size)	0.00692	176	3.28
ISLAB2000 (6" mesh size)	0.00690	175	2.99
ISLAB2000 (3" mesh size)	0.00689	175	2.84

Table B-8: Deflection result comparison

Approach	Maximum Curling Stress		Difference (%)
	(psi)	(kPa)	
Westergaard's	143.7	991	0.00
ISLAB2000 (24" mesh size)	140.6	969	2.16
ISLAB2000 (12" mesh size)	159.0	1096	10.65
ISLAB2000 (6" mesh size)	151.9	1047	5.69
ISLAB2000 (3" mesh size)	144.2	994	0.35

Problem 4 (Example 4.4 page 178 in the textbook)

Textbook solution

Given: Concrete elastic modulus = $4*10^6$ psi
Concrete Poisson ratio = 0.15
Slab thickness = 10 in.
k-value = 100 psi/in.
Tire contact radius = 6 in.
Wheel load = 10,000 lb

Find: (a) The maximum stress due to edge loading
(b) The maximum deflection due to edge loading

Problem illustration:

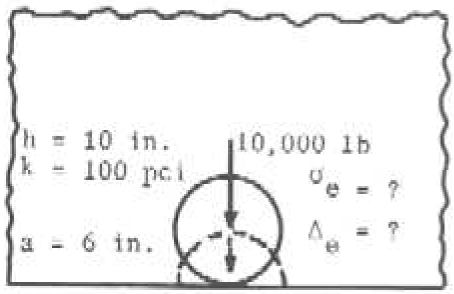

Figure B-9: Problem illustration (Figure 4.9 in the textbook)

Solutions (based on Westergaard's equations):

(a) The maximum stress due to edge loading = 279.4 psi (1926 kPa)
(b) The maximum deflection due to edge loading = 0.0207 in. (526 microns)

FE solution

Figures A10 and A11 represent the mesh used in the analysis.

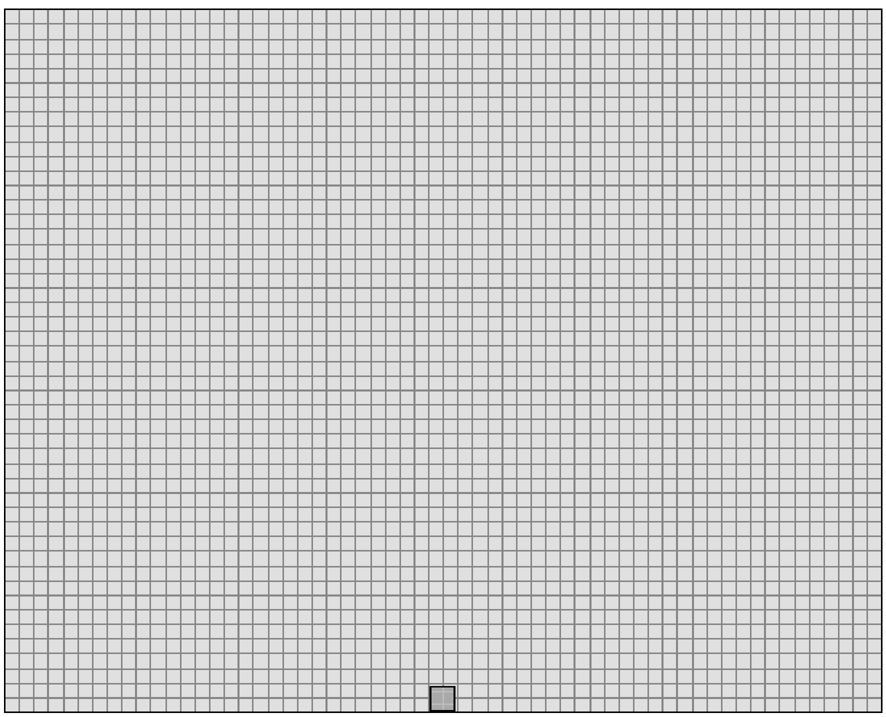

Figure B-10: Mesh used for finite element model in ISLAB2000

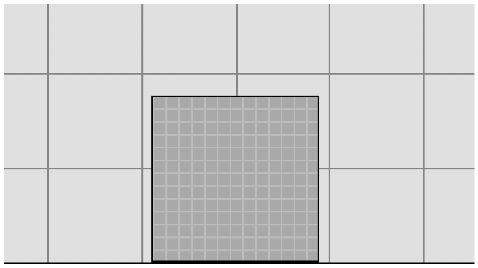

Figure B-11: Equivalent square contact area used in ISLAB2000

Numerical outputs:

<u>For fine mesh</u>:
The maximum stress due to edge loading = 294.9 psi (2033 kPa)
The maximum deflection due to edge loading = 0.0212 in. (538 microns)
<u>For medium mesh</u>:
The maximum stress due to edge loading = 306.5 psi (2113 kPa)
The maximum deflection due to edge loading = 0.0212 in. (538 microns)
<u>For coarse mesh</u>:
The maximum stress due to edge loading = 285.9 psi (1971 kPa)
The maximum deflection due to edge loading = 0.0211 in. (537 microns)
<u>For manual mesh</u>:
The maximum stress due to edge loading = 287.2 psi (1980 kPa)
The maximum deflection due to edge loading = 0.0212 in. (538 microns)

Result comparison:

Table B-9: Stress result comparison

Approach	Maximum Curling Stress		Difference (%)
	(psi)	(kPa)	
Westergaard's	279.4	1926	0.00
ISLAB2000 (24" mesh size)	285.9	1971	2.33
ISLAB2000 (12" mesh size)	306.5	2113	9.70
ISLAB2000 (6" mesh size)	294.9	2033	5.54
ISLAB2000 (3" mesh size)	287.2	1980	2.79

Table B-10: Deflection result comparison

Approach	Maximum Deflection		Difference (%)
	(in.)	(microns)	
Westergaard's	0.0207	526	0.00
ISLAB2000 (24" mesh size)	0.0211	537	2.08
ISLAB2000 (12" mesh size)	0.0212	538	2.32
ISLAB2000 (6" mesh size)	0.0212	538	2.42
ISLAB2000 (3" mesh size)	0.0212	538	2.42

Problem 5 (Example 4.5 page 180 in the textbook)

Textbook solution

Given:	Concrete elastic modulus	=	$4*10^6$	psi
	Concrete Poisson ratio	=	0.15	
	Slab thickness	=	10	in.
	k-value	=	100	psi/in.
	Dual tire spacing	=	14	in.
	Tire contact pressure	=	88.42	psi
	Wheel load	=	10,000	lb (5,000 lb each)

Find: (a) The maximum stress due to corner loading
(b) The maximum stress due to interior loading
(c) The maximum stress due to edge loading

Problem illustration:

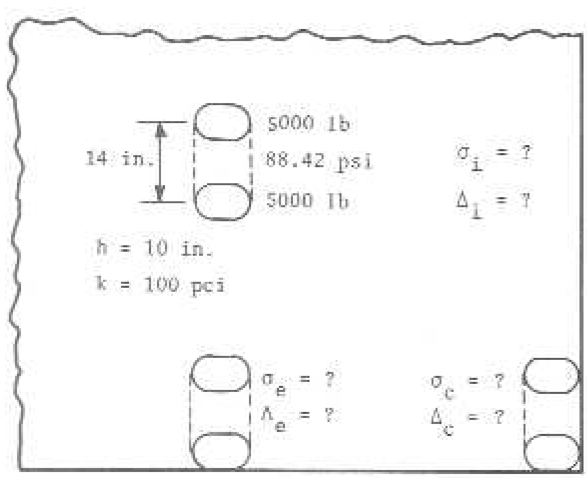

Figure B-12: Problem illustration (Figure 4.11 in the textbook)

Solutions (based on Westergaard's equations):

(a) The maximum stress due to corner loading = 166.8 psi (1150 kPa)
(b) The maximum stress due to interior loading = 130.8 psi (902 kPa)
(c) The maximum stress due to edge loading = 244.2 psi (1684 kPa)

FE solution

Summary of inputs: All pavement features used in this part are the same as indicated in the textbook solution. However, the circular tire contact area as illustrated in the problem was not the option in ISLAB2000. As a result, a square tire contact area with the same tire contact pressure and wheel load was used instead. The tire pressure was computed as follows.

Radius of contact area,

$$a = \sqrt{\frac{0.8521 \cdot P_d}{q \cdot \pi} + \frac{S_d}{\pi} \cdot \left(\frac{P_d}{0.5227 \cdot q} \right)^{1/2}} \quad \text{(A-2, Eq. 4.31 in the textbook)}$$

$$= \sqrt{\frac{0.8521 \times 5000}{88.42} + \frac{14}{\pi} \cdot \left(\frac{5000}{0.5227 \times 88.42} \right)^{1/2}} = 7.85 \quad in.$$

Tire contact pressure, $q = \dfrac{P}{\pi \cdot a^2} = \dfrac{10{,}000}{\pi \cdot 7.85^2} = 51.65 \quad psi$

A fine mesh size (6") with an aspect ratio of one was used for this analysis and is illustrated in Figures A13-A18.

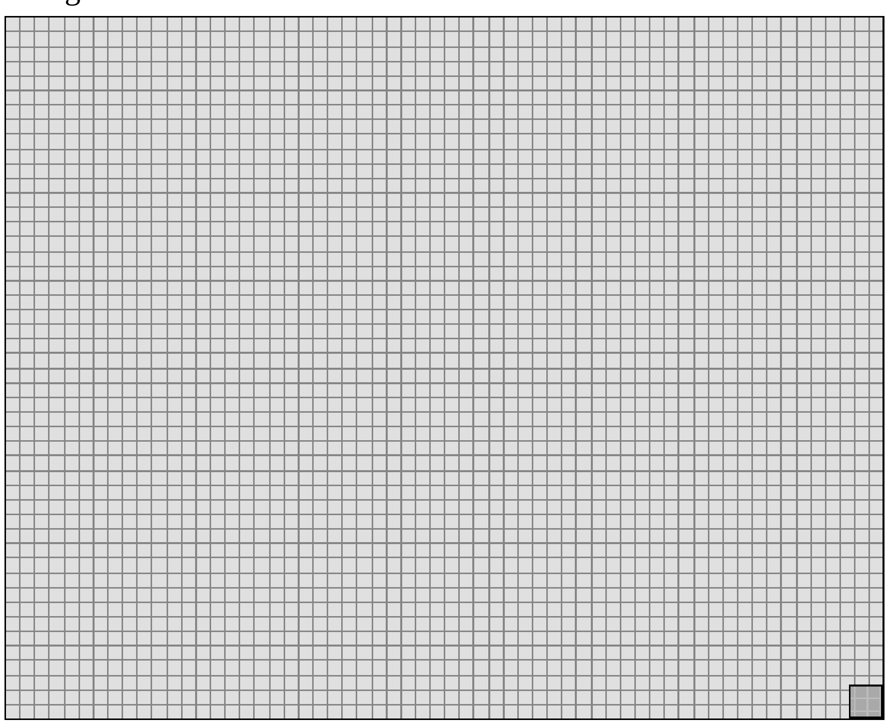

Figure B-13: Mesh used for finite element model for corner loading in ISLAB2000

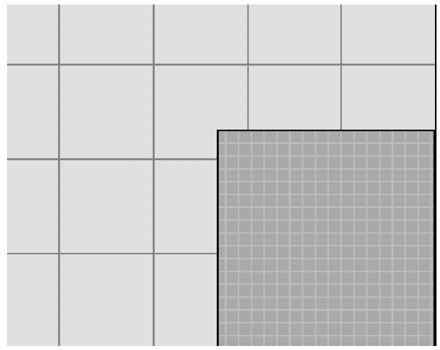

Figure B-14: Equivalent square contact area used for corner loading in ISLAB2000

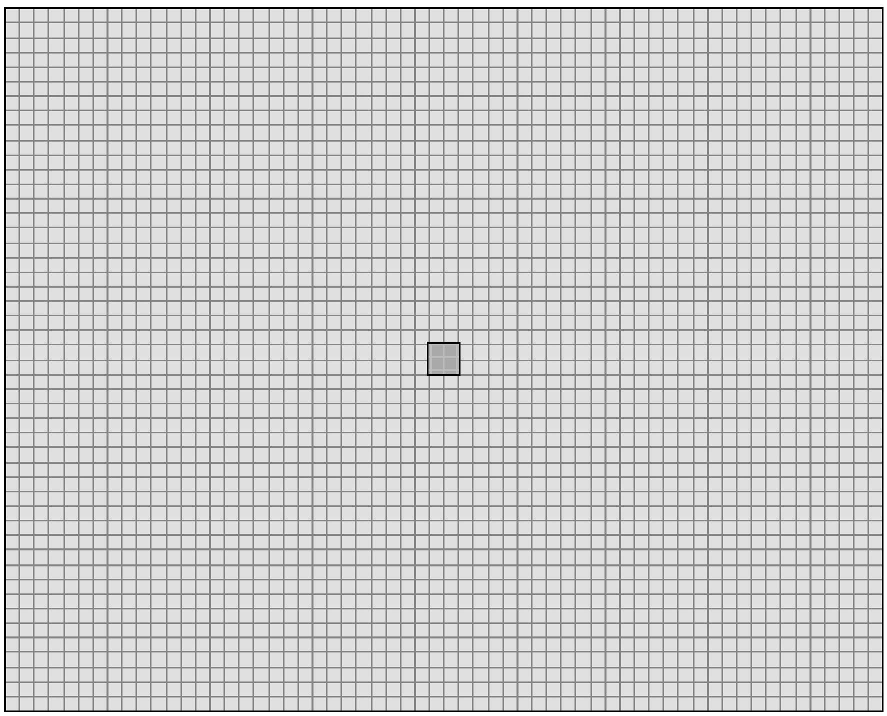

Figure B-15: Mesh used for finite element model for interior loading in ISLAB2000

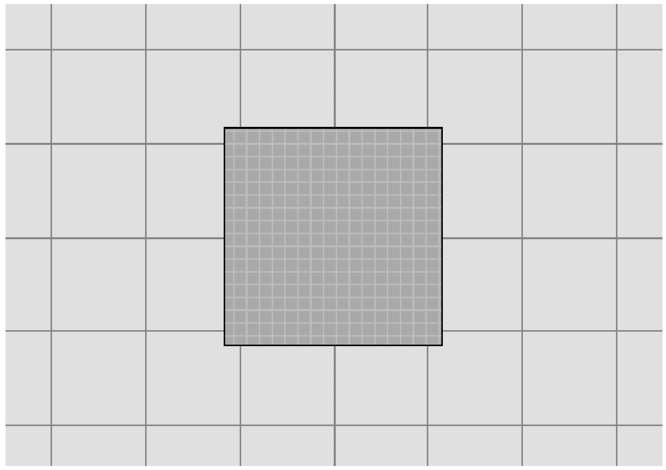

Figure B-16: Equivalent square contact area used for interior loading in ISLAB2000

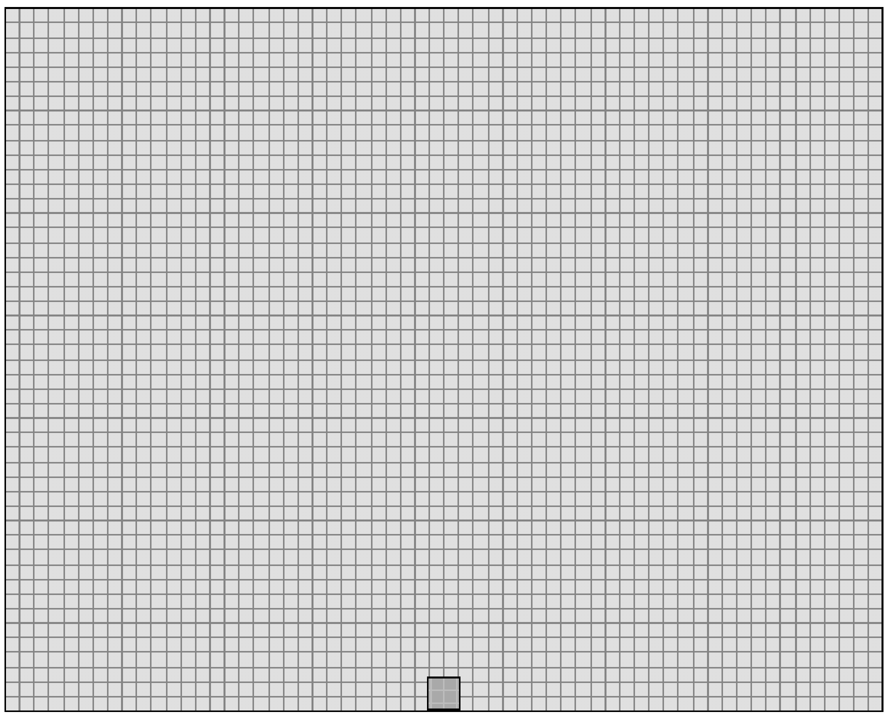

Figure B-17: Mesh used for finite element model for edge loading in ISLAB2000

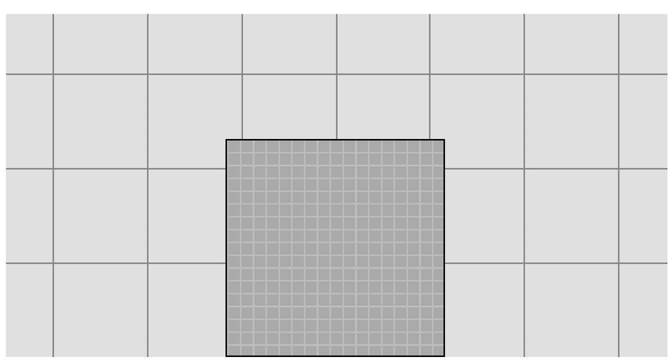

Figure B-18: Equivalent square contact area used for edge loading in ISLAB2000

Numerical outputs:

For fine mesh:
The maximum stress due to corner loading = 177.6 psi (1225 kPa)
The maximum stress due to interior loading = 132.8 psi (916 kPa)
The maximum stress due to edge loading = 255.2 psi (1760 kPa)
For medium mesh:
The maximum stress due to corner loading = 178.1 psi (1228 kPa)
The maximum stress due to interior loading = 144.2 psi (994 kPa)
The maximum stress due to edge loading = 267.6 psi (1845 kPa)
For coarse mesh:
The maximum stress due to corner loading = 182.3 psi (1257 kPa)
The maximum stress due to interior loading = 135.5 psi (934 kPa)
The maximum stress due to edge loading = 263.8 psi (1819 kPa)

Result comparison:

Table B-11: Stress result comparison for corner loading

Approach	Maximum Curling Stress		Difference (%)
	(psi)	(kPa)	
Westergaard's	166.8	1150	0.00
ISLAB2000 (24" mesh size)	182.3	1257	9.29
ISLAB2000 (12" mesh size)	178.1	1228	6.77
ISLAB2000 (6" mesh size)	177.6	1225	6.47

Table B-12: Stress result comparison for interior loading

Approach	Maximum Curling Stress		Difference (%)
	(psi)	(kPa)	
Westergaard's	130.8	902	0.00
ISLAB2000 (24" mesh size)	135.5	934	3.59
ISLAB2000 (12" mesh size)	144.2	994	10.24
ISLAB2000 (6" mesh size)	132.8	916	1.54

Table B-13: Stress result comparison for edge loading

Approach	Maximum Curling Stress		Difference (%)
	(psi)	(kPa)	
Westergaard's	244.2	1684	0.00
ISLAB2000 (24" mesh size)	263.8	1819	8.03
ISLAB2000 (12" mesh size)	267.6	1845	9.58
ISLAB2000 (6" mesh size)	255.2	1760	4.50

Problem 6 (Problem 4-1 page 203 in the textbook)

Textbook solution

Given: Concrete elastic modulus	=	$4*10^6$	psi	
Concrete Poisson ratio	=	0.15		
Slab length	=	20	ft	(for part b.)
Slab width	=	12	ft	(for part b.)
Slab thickness	=	8	in.	
Temperature differential	=	24	^oF	
k-value	=	50	psi/in.	
α_t	=	$5*10^{-6}$	in./in./ ^oF	

Find: a) for an infinite slab

The maximum curling stress in the interior of the slab

The maximum curling stress at the edge of the slab

b) for a finite slab

The maximum curling stress at points A, B, and C in the Figure P4.1

Problem illustration:

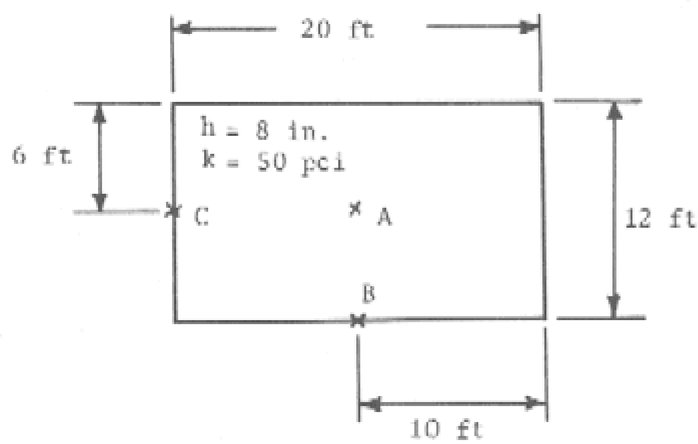

Figure B-19: Problem illustration (Figure P4.1 in the textbook)

Solutions (based on Westergaard's equations):

(a) for an infinite slab

The maximum curling stress in the interior of the slab= 282.4 psi (1947 kPa)

The maximum curling stress at the edge of the slab = 240.0 psi (1655 kPa)

(b) for a finite slab

The maximum curling stress at points A = 211.4 psi (1458 kPa)

The maximum curling stress at points B = 198.0 psi (1365 kPa)

The maximum curling stress at points C = 57.6 psi (397 kPa)

FE solution

Summary of inputs: All pavement features and temperature gradient used in this part are the same as indicated in the textbook solution. The slab dimension of 48' by 60' was used to represent the infinite slab. A fine mesh with an aspect ratio of one was chosen and is illustrated in Figures A20 and A21.

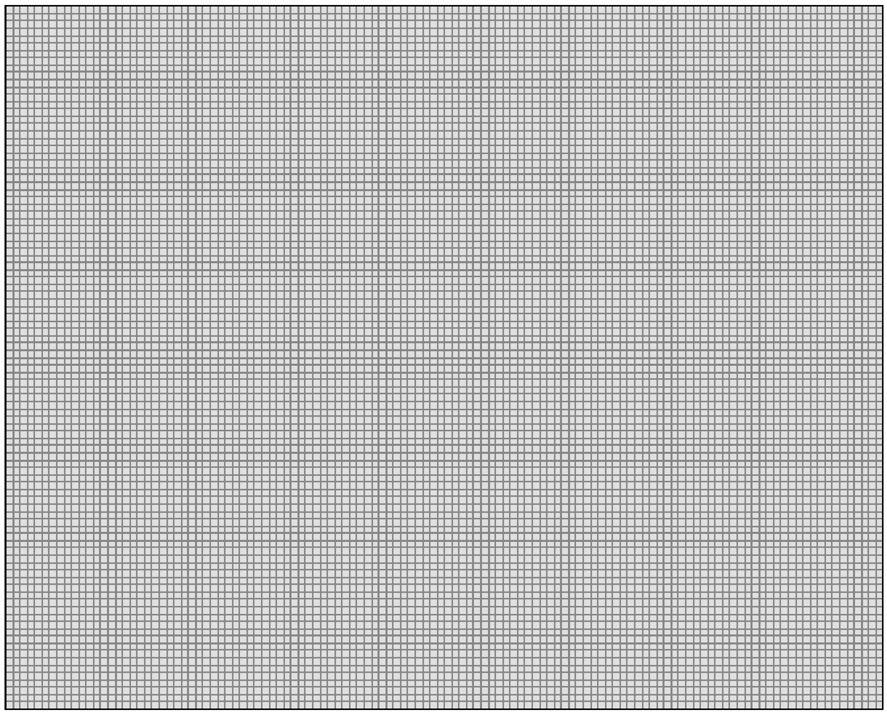

Figure B-20: Mesh used for finite element model for an infinite slab in ISLAB2000

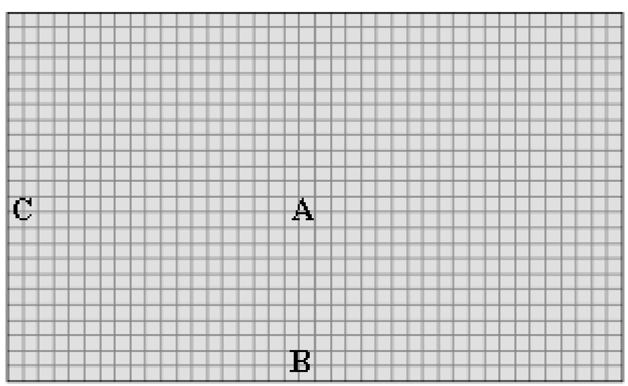

Figure B-21: Mesh used for finite element model for a finite slab in ISLAB2000

Numerical outputs:

I. For an infinite slab

For fine mesh:

The maximum curling stress in the interior of the slab	=	296.2	psi (2042 kPa)
The maximum curling stress at the edge of the slab	=	245.3	psi (1692 kPa)

For medium mesh:

The maximum curling stress in the interior of the slab	=	296.3	psi (2043 kPa)
The maximum curling stress at the edge of the slab	=	244.9	psi (1689 kPa)

For coarse mesh:

The maximum curling stress in the interior of the slab	=	296.6	psi (2045 kPa)
The maximum curling stress at the edge of the slab	=	244.2	psi (1684 kPa)

II. For a finite slab

For fine mesh:

The maximum curling stress at points A	=	194.8	psi (1343 kPa)
The maximum curling stress at points B	=	196.0	psi (1351 kPa)
The maximum curling stress at points C	=	49.7	psi (343 kPa)

For medium mesh:

The maximum curling stress at points A	=	195.3	psi (1347 kPa)
The maximum curling stress at points B	=	196.3	psi (1353 kPa)
The maximum curling stress at points C	=	49.9	psi (344 kPa)

For coarse mesh:

The maximum curling stress at points A	=	197.3	psi (1360 kPa)
The maximum curling stress at points B	=	197.8	psi (1364 kPa)
The maximum curling stress at points C	=	50.4	psi (347 kPa)

Result comparison:

Table B-14: The maximum curling stress comparison in the interior of an infinite slab

Approach	Maximum Curling Stress		Difference (%)
	(psi)	(kPa)	
Westergaard's	282.4	1947	0.00
ISLAB2000 (24" mesh size)	296.6	2045	5.03
ISLAB2000 (12" mesh size)	296.3	2043	4.92
ISLAB2000 (6" mesh size)	296.2	2042	4.89

Table B-15: The maximum curling stress comparison at the edge of an infinite slab

Approach	Maximum Curling Stress		Difference (%)
	(psi)	(kPa)	
Westergaard's	240.0	1655	0.00
ISLAB2000 (24" mesh size)	244.2	1684	1.74
ISLAB2000 (12" mesh size)	244.9	1689	2.05
ISLAB2000 (6" mesh size)	245.4	1692	2.23

Table B-16: The maximum curling stress comparison at points A of a finite slab

Approach	Maximum Curling Stress		Difference (%)
	(psi)	(kPa)	
Westergaard's	211.4	1458	0.00
ISLAB2000 (24" mesh size)	197.3	1360	6.69
ISLAB2000 (12" mesh size)	195.3	1347	7.62
ISLAB2000 (6" mesh size)	194.8	1343	7.87

Table B-17: The maximum curling stress comparison at points B of a finite slab

Approach	Maximum Curling Stress		Difference (%)
	(psi)	(kPa)	
Westergaard's	198.0	1365	0.00
ISLAB2000 (24" mesh size)	197.8	1364	0.09
ISLAB2000 (12" mesh size)	196.3	1353	0.86
ISLAB2000 (6" mesh size)	196.0	1351	1.04

Table B-18: The maximum curling stress comparison at points C of a finite slab

Approach	Maximum Curling Stress		Difference (%)
	(psi)	(kPa)	
Westergaard's	57.6	397	0.00
ISLAB2000 (24" mesh size)	50.4	347	12.55
ISLAB2000 (12" mesh size)	49.9	344	13.42
ISLAB2000 (6" mesh size)	49.7	343	13.65

Problem 7 (Problem 4-2 page 204 in the textbook)

Textbook solution

Given: Concrete elastic modulus	=	$4*10^6$	psi
Concrete Poisson ratio	=	0.15	
Slab thickness	=	10	in.
k-value	=	200	psi/in.
Tire contact pressure	=	80	psi
Wheel load	=	12,000	lb (6,000 lb each)
Dual tire spacing	=	14	in.

Find: (a) The maximum stress due to corner loading

Problem illustration:

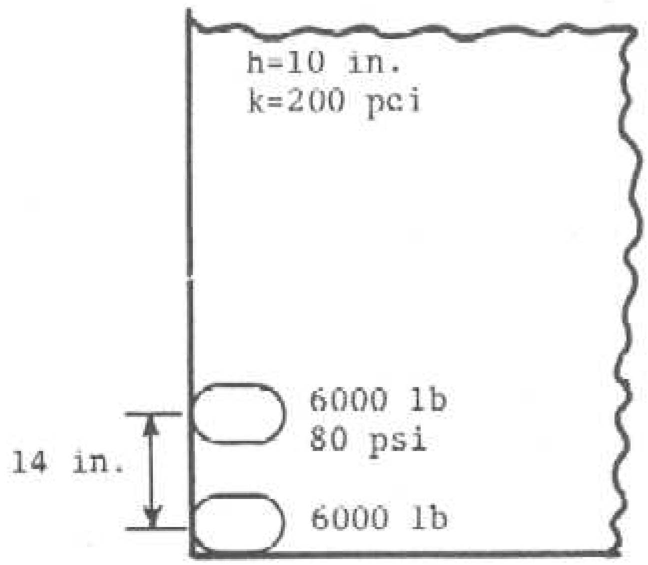

Figure B-22: Problem illustration (Figure P4.2 in the textbook)

Solutions (based on Westergaard's equations):

(a) The maximum stress due to corner loading = 172.8 psi (1191 kPa)

FE solution

Summary of inputs: All pavement features used in this part are the same as indicated in the textbook solution. However, the circular tire contact area as illustrated in the problem was not the option in ISLAB2000. As a result, a square tire contact area with the same tire contact pressure and wheel load was used instead. It should be noted that this tire contact pressure will also be used in problem 8 and 9. The tire pressure was computed as follows.

Radius of contact area,

$$a = \sqrt{\frac{0.8521 \cdot P_d}{q \cdot \pi} + \frac{S_d}{\pi} \cdot \left(\frac{P_d}{0.5227 \cdot q} \right)^{1/2}} \quad \text{(A-2, Eq. 4.31 in the textbook)}$$

$$= \sqrt{\frac{0.8521 \times 6000}{80} + \frac{14}{\pi} \cdot \left(\frac{6000}{0.5227 \times 80} \right)^{1/2}} = 10.83 \quad in.$$

Tire contact pressure, $q = \dfrac{P}{\pi \cdot a^2} = \dfrac{12{,}000}{\pi \cdot 10.83^2} = 32.57 \quad psi$

Figures A23 and A24 represent the mesh used in the analysis.

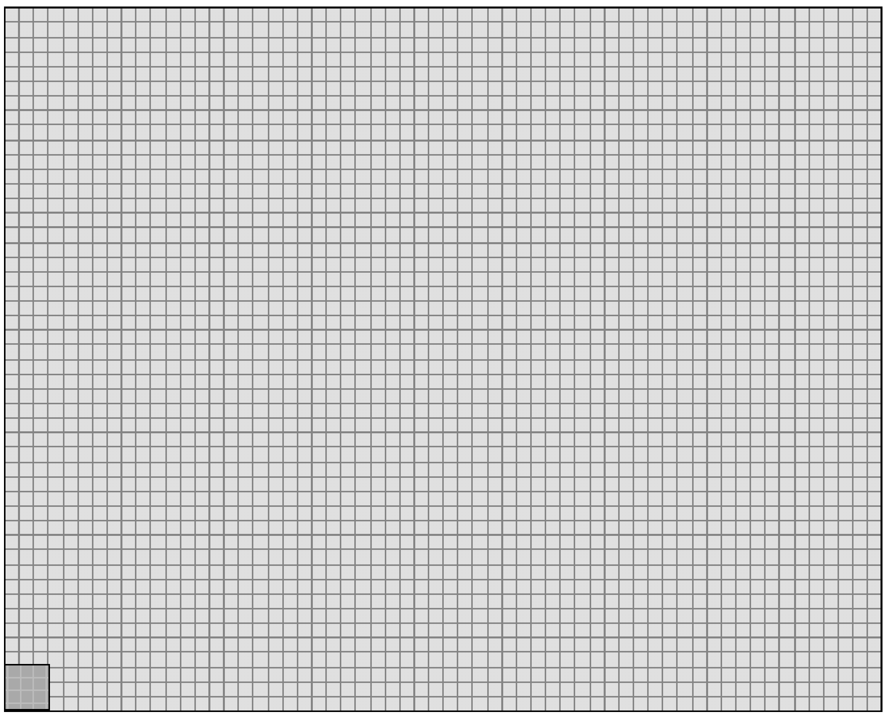

Figure B-23: Mesh used for finite element model in ISLAB2000

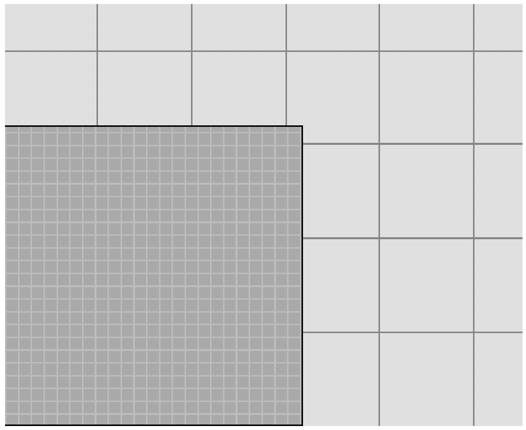

Figure B-24: Equivalent square contact area used in ISLAB2000

Numerical outputs:

For fine mesh:
The maximum stress due to corner loading = 164.5 psi (1134 kPa)
For medium mesh:
The maximum stress due to corner loading = 166.5 psi (1148 kPa)
For coarse mesh:
The maximum stress due to corner loading = 171.1 psi (1180 kPa)

Result comparison:

Table B-19: Stress result comparison for corner loading

Approach	Maximum Curling Stress		Difference (%)
	(psi)	(kPa)	
Westergaard's	172.8	1191	0.00
ISLAB2000 (24" mesh size)	171.1	1180	0.98
ISLAB2000 (12" mesh size)	166.5	1148	3.65
ISLAB2000 (6" mesh size)	164.5	1134	4.80

Problem 8 (Problem 4-3 page 204 in the textbook)

Textbook solution

Given:	Concrete elastic modulus	=	$4*10^6$	psi
	Concrete Poisson ratio	=	0.15	
	Slab thickness	=	10	in.
	k-value	=	200	psi/in.
	Tire contact pressure	=	80	psi
	Wheel load	=	12,000	lb (6,000 lb each)
	Dual tire spacing	=	14	in.

Find: (a) The maximum stress due to interior loading

Problem illustration:

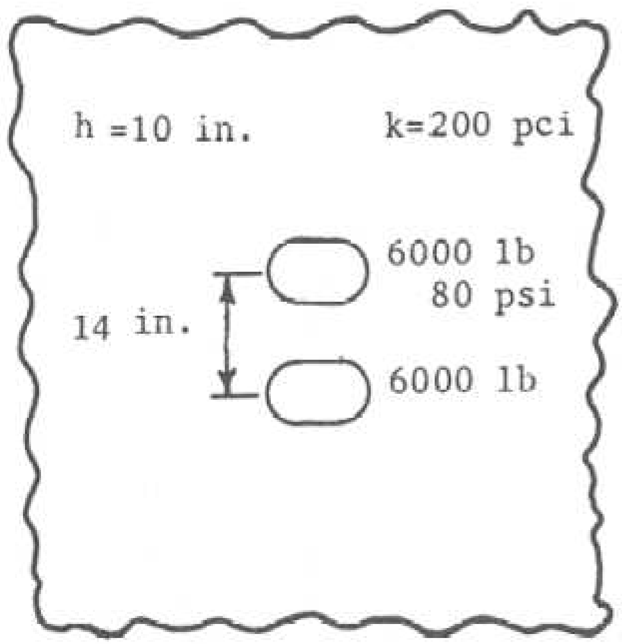

Figure B-25: Problem illustration (Figure P4.3 in the textbook)

Solutions (based on Westergaard's equations):

(a) The maximum stress due to interior loading = 139.7 psi (963 kPa)

FE solution

Figures A26 and A27 represent the mesh used in the analysis.

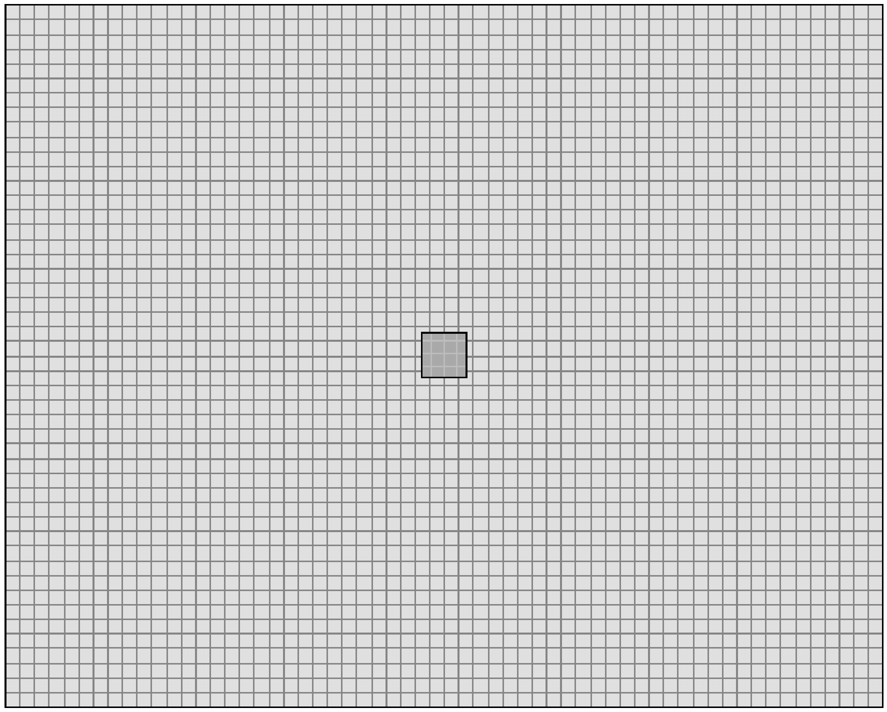

Figure B-26: Mesh used for finite element model in ISLAB2000

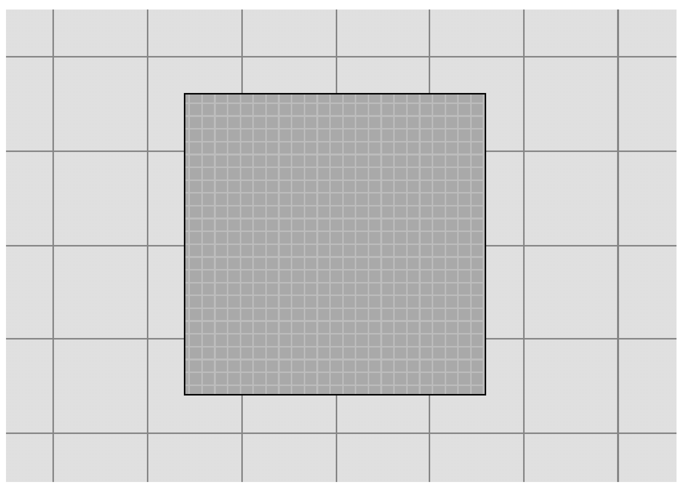

Figure B-27: Equivalent square contact area used in ISLAB2000

Numerical outputs:

For fine mesh:
The maximum stress due to interior loading = 123.3 psi (850 kPa)
For medium mesh:
The maximum stress due to interior loading = 134.1 psi (925 kPa)
For coarse mesh:
The maximum stress due to interior loading = 137.6 psi (949 kPa)

Result comparison:

Table B-20: Stress result comparison for interior loading

Approach	Maximum Curling Stress		Difference (%)
	(psi)	(kPa)	
Westergaard's	139.7	963	0.00
ISLAB2000 (24" mesh size)	137.6	949	1.50
ISLAB2000 (12" mesh size)	134.1	925	4.01
ISLAB2000 (6" mesh size)	123.3	850	11.74

Problem 9 (Problem 4-4 page 204 in the textbook)

Textbook solution

Given: Concrete elastic modulus = $4*10^6$ psi
Concrete Poisson ratio = 0.15
Slab thickness = 10 in.
k-value = 200 psi/in.
Tire contact pressure = 80 psi
Wheel load = 12,000 lb (6,000 lb each)
Dual tire spacing = 14 in.

Find: (a) The maximum stress due to edge loading

Problem illustration:

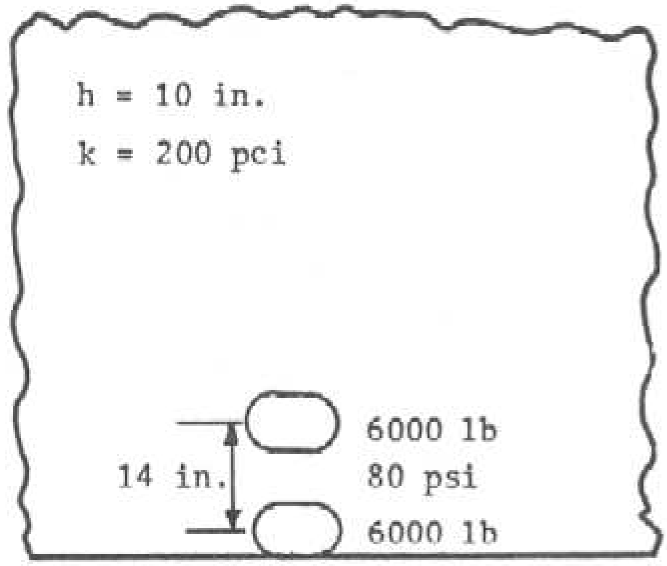

Figure B-28: Problem illustration (Figure P4.4 in the textbook)

Solutions (based on Westergaard's equations):

(a) The maximum stress due to edge loading = 252.5 psi (1741 kPa)

FE solution

Figures A29 and A30 represent the mesh used in the analysis.

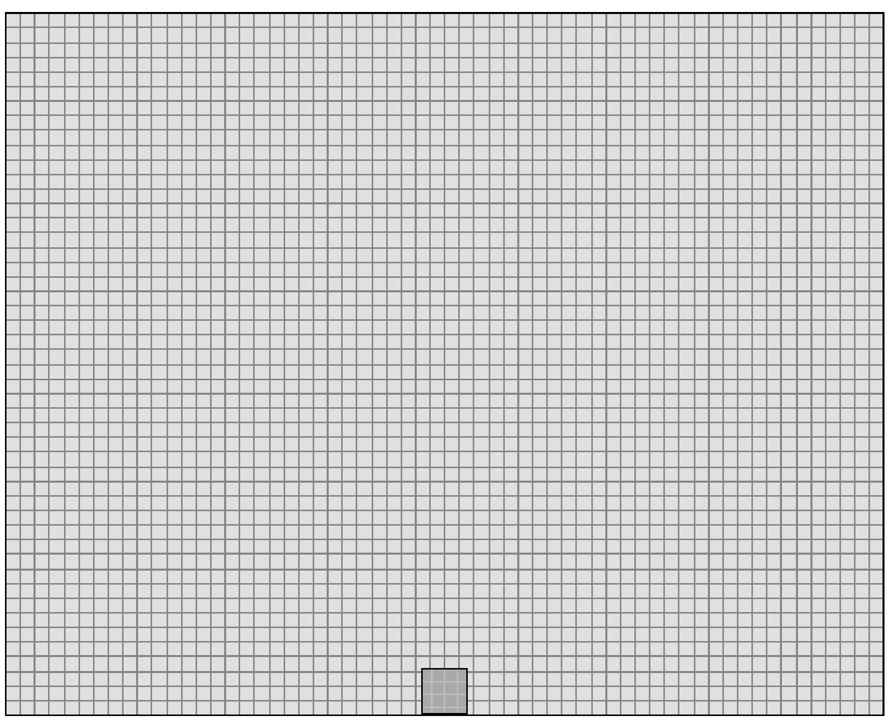

Figure B-29: Mesh used for finite element model in ISLAB2000

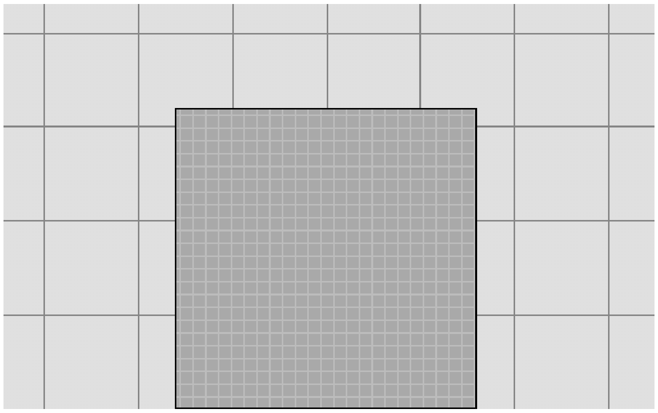

Figure B-30: Equivalent square contact area used in ISLAB2000

Numerical outputs:

For fine mesh:

The maximum stress due to edge loading = 227.4 psi (1568 kPa)

For medium mesh:

The maximum stress due to edge loading = 237.9 psi (1640 kPa)

For coarse mesh:

The maximum stress due to edge loading = 247.7 psi (1708 kPa)

Result comparison:

Table B-21: Stress result comparison for edge loading

Approach	Maximum Curling Stress		Difference (%)
	(psi)	(kPa)	
Westergaard's	252.5	1741	0.00
ISLAB2000 (24" mesh size)	247.7	1708	1.90
ISLAB2000 (12" mesh size)	237.9	1640	5.78
ISLAB2000 (6" mesh size)	227.4	1568	9.94